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FULL-SCALE WIND-TUNNEL INVESTIGATION OF A TARGET-TYPE THRUST REVERSER ON THE A-37B AIRPLANE

by

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16. Abstract

Full-scale wind-tunnel tests were conducted to determine the aerodynamic characteristics of the A-37B airplane equipped with target-type thrust reversers. Operation of the reversers caused large decreases in longitudinal stability and control and severe airplane buffetting. Exposure to the exhaust gas plumes caused failure of the flap and reverser control mechanisms and caused skin distortion. Reverser operation in ground effect was limited by exhaust gas ingestion into the engine inlets.

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NOTATION

$\bar{c}$ wing mean aerodynamic chord, ft

C_D drag coefficient, $\frac{\text{drag}}{qS}$

C_L lift coefficient, $\frac{\text{lift}}{qS}$

C_m pitching-moment coefficient, $\frac{\text{pitching moment}}{qS\bar{c}}$

F_g gross thrust, lb

N percent of engine rated rpm

q free-stream dynamic pressure, lb/ft^2

S wing area, ft^2

α angle of attack, deg

δ_e elevator deflection positive up, deg

θ temperature ratio, $\frac{\text{free-stream air temperature, } ^\circ R}{\text{standard temperature, } ^\circ R}$

Subscript

u uncorrected

The data presented are referred to the wind axis.

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SUMMARY

Full-scale wind-tunnel tests were conducted to determine the aerodynamic characteristics of the A-37B airplane equipped with target-type thrust reversers. Operation of the reversers caused large decreases in longitudinal stability and control and severe airplane buffetting. Exposure to the exhaust gas plumes caused failure of the flap and reverser control mechanisms and caused skin distortion. Reverser operation in ground effect was limited by exhaust gas ingestion into the engine inlets.

INTRODUCTION

Thrust reversers have shown potential for allowing more precise control of aircraft flight path and approach speed through rapid modulation of thrust (see, e.g., refs. 1 and 2). A study of the application of a target-type thrust reverser to the A-37B airplane was made in Ames 40- by 80-Foot Wind Tunnel, and the results are reported herein.

MODEL AND APPARATUS

The A-37B airplane used in the tests is shown in figure 1. The wind-tunnel installation of the airplane is shown in figure 2(a), and the ground plane installation used to study exhaust ingestion during landing is shown in figure 2(b).

The airplane was equipped with two J-85-17A turbojet engines with target-type reverser assemblies. The details of the reversers are shown in the sketch and photographs of figures 3 and 4.

TEST PROCEDURE

The effectiveness of the reverser was determined by setting a reverser door gap and varying engine speed. This procedure was duplicated for several door gaps from 0 (full reverse) to 17.4 (stowed) inches and free-stream dynamic pressures from 0 to 60 psf.

To determine the effect of the reversers on the longitudinal aerodynamic characteristics the angle of attack was varied from -3° to +16° at a constant corrected engine speed and free-stream dynamic pressure. This was done for several speeds at each of several reverser door gaps. Elevator deflection was varied from -20° to +5°. The flaps were set at 0° because of control mechanism failure.

Exhaust gas ingestion studies were performed with the ground plane installed under the airplane at the landing touchdown height. Exhaust gas ingestion was determined with thermocouples mounted in the engine inlet. The engine speed at which exhaust gas ingestion occurred was defined for several door gaps by increasing engine speed while holding a constant free-stream dynamic pressure of 30 psf. For these tests the airplane flaps and angle of attack were set at 0°.

CORRECTIONS

The following corrections for wind-tunnel-wall effects were made to the force data:

$$\alpha = \alpha_u + 0.409\ C_{L_u}$$

$$C_D = C_{D_u} + 0.00698\ C_{L_u}^{\ 2}$$

$$C_m = C_{m_u} + 0.00754\ C_{L_u}$$

The model drag and pitching moment were corrected for tares obtained for the unshielded strut tips. These tares were obtained without the model and therefore do not include the aerodynamic interaction between the model and strut tips.

ACCURACY OF MEASUREMENTS

The various quantities measured in the wind tunnel were accurate within the following limits:

Angle of attack	±0.3°
Lift	±10 lb
Drag	±3 lb
Pitching moment	±250 ft-lb
Free-stream dynamic pressure	±0.5 percent
Door gap	±1/16 inch
Elevator deflection	±1.0°

The force and moment data were obtained by averaging several samples for each data point. The accuracies include errors due to correction, calibration, and recording method.

RESULTS AND DISCUSSION

The thrust reverser effectiveness is presented in figures 5 and 6. The variation of gross thrust with corrected engine speed for several door gaps at a free-stream dynamic pressure (q) of 0 psf is presented in figure 5. The variation of drag coefficient with corrected engine speed for several door gaps at a q of about 30 psf is presented in figure 6. At a corrected speed of about 77 percent, data for a few additional values of q are shown.

As can be seen in figures 5 and 6, the engine speed during reverser operation did not exceed 80 percent because of heating problems caused by the reverser exhaust plumes. Exposure to exhaust gases caused engine overheating and failure of the flap and reverser control mechanisms. The lower exhaust plume attached to the nacelle and fuselage lower surfaces causing discoloration and skin distortion as shown in figure 7. This occurred with and without the ground plane installed. The occurrence of this exhaust flow attachment was delayed by removal of the reverser door end plates. Attachment was further delayed by the addition of spoilers on the nacelle. For a door gap of 5-1/4 inches and q = 20 psf, a 1.7-inch-high spoiler delayed exhaust plume attachment from an engine speed of 60 to 80 percent. All the data presented are for both spoiler and end plates removed.

The longitudinal characteristics of the A-37B airplane are presented in figures 8 to 10 for various reverser door gaps and engine speeds. It is evident that the stability and control effectiveness of the aircraft is reduced as the reverser door gap is reduced. For a given door gap the stability is also reduced as the engine speed is increased. The large scatter in the stability data is due to turbulence created at the horizontal tail by the reverser exhaust plumes. This turbulence was evident as severe airplane buffet that increased with reversed thrust.

Exhaust ingestion was defined by a sudden fluctuation and rise in the engine inlet air temperature. It occurred when the exhaust plume from the lower reverser door was deflected forward under the wing by the ground plane. The exhaust then entered the engine at the lower edge of the inlet. The results of the ingestion study are presented in figure 11. This figure shows the corrected engine speed at which ingestion occurs as a function of reverser door gap for a free-stream dynamic pressure of 30 psf.

CONCLUDING REMARKS

As reversed thrust was increased, either by reducing reverser door gap or increasing engine speed, longitudinal stability and control was reduced because the reverser exhaust plumes interferes with the horizontal tail. This interference also caused tail buffetting that increased with increasing reversed thrust.

Operation of the thrust reversers in ground effect was severely limited by ingestion of the lower portion of the exhaust plume into the engine inlets.

Maximum engine speed during reverser operation was limited to 80 percent by nacelle heating caused by the reverser exhaust plumes.

Ames Research Center
National Aeronautics and Space Administration
Moffett Field, Calif. 94035, Dec. 10, 1969

REFERENCES

1. Anderson, Seth B.; Cooper, George E.; and Faye, Alan E., Jr.: Flight Measurement of the Effect of a Controllable Thrust Reverser on the Flight characteristics of a Single-Engine Jet Airplane. NASA MEMO 4-26-59A, 1959.

2. Tolhurst, William H., Jr.; Kelly, Mark W.; and Greif, Richard K.: Full-Scale Wind-Tunnel Investigation of the Effect of a Target-Type Thrust Reverser on the Low-Speed Aerodynamic Characteristics of a Single-Engine Jet Airplane. NASA TN D-72, 1959.

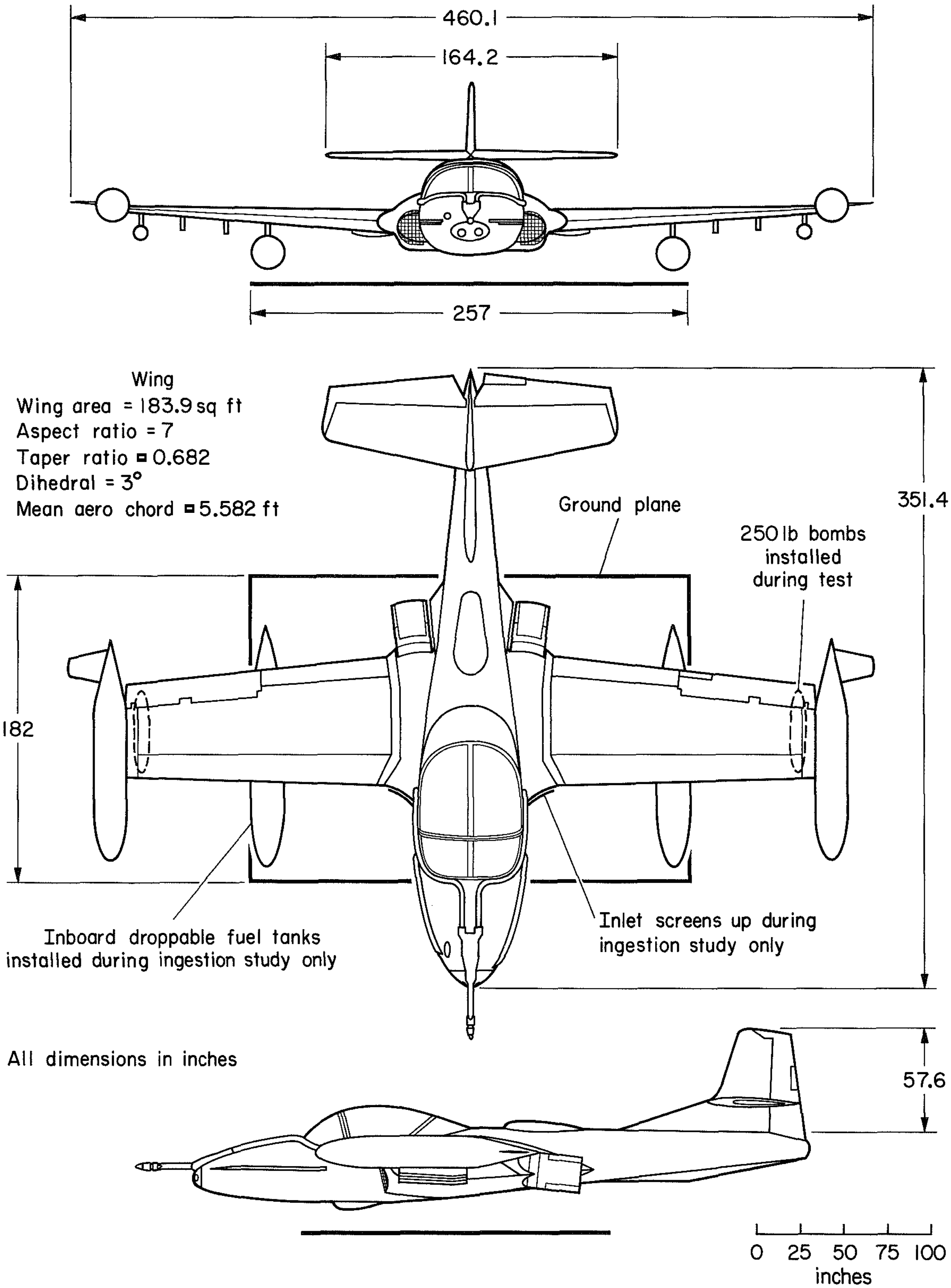
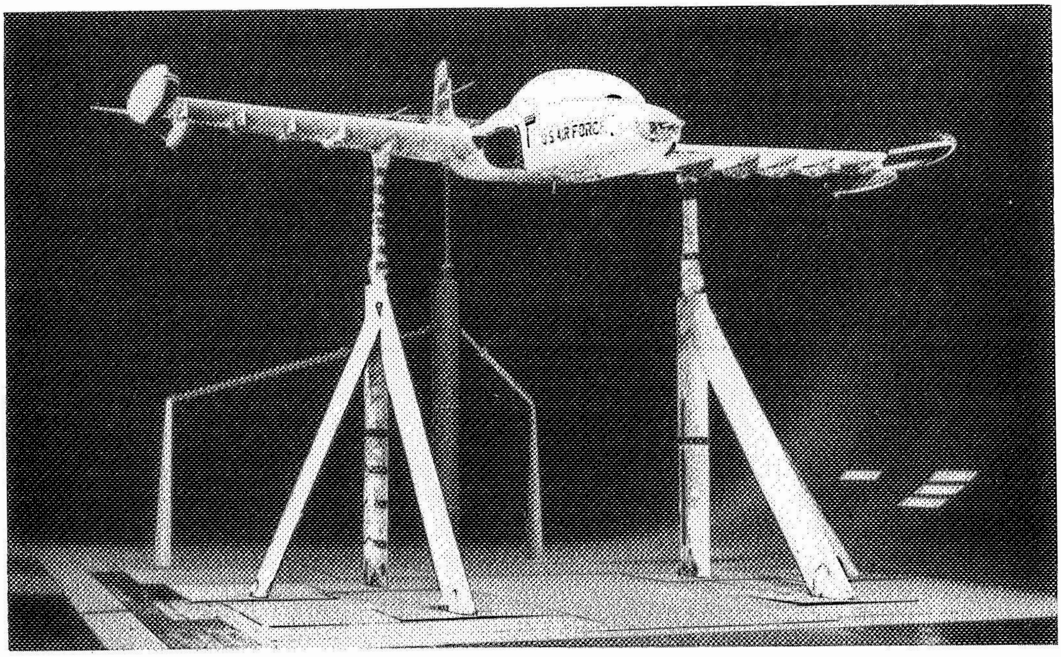
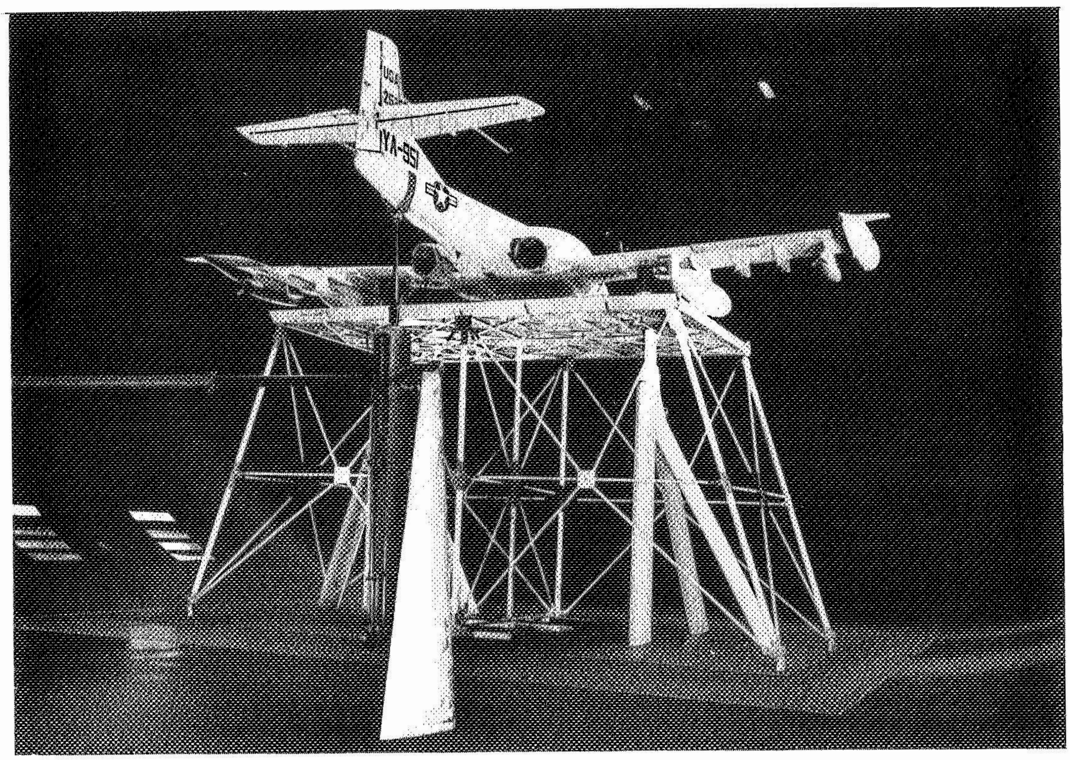


Figure 1.- Model details; all dimensions in inches.



(a) Ground plane removed.



(b) Ground plane installed.

Figure 2.- Aircraft installed in wind tunnel.

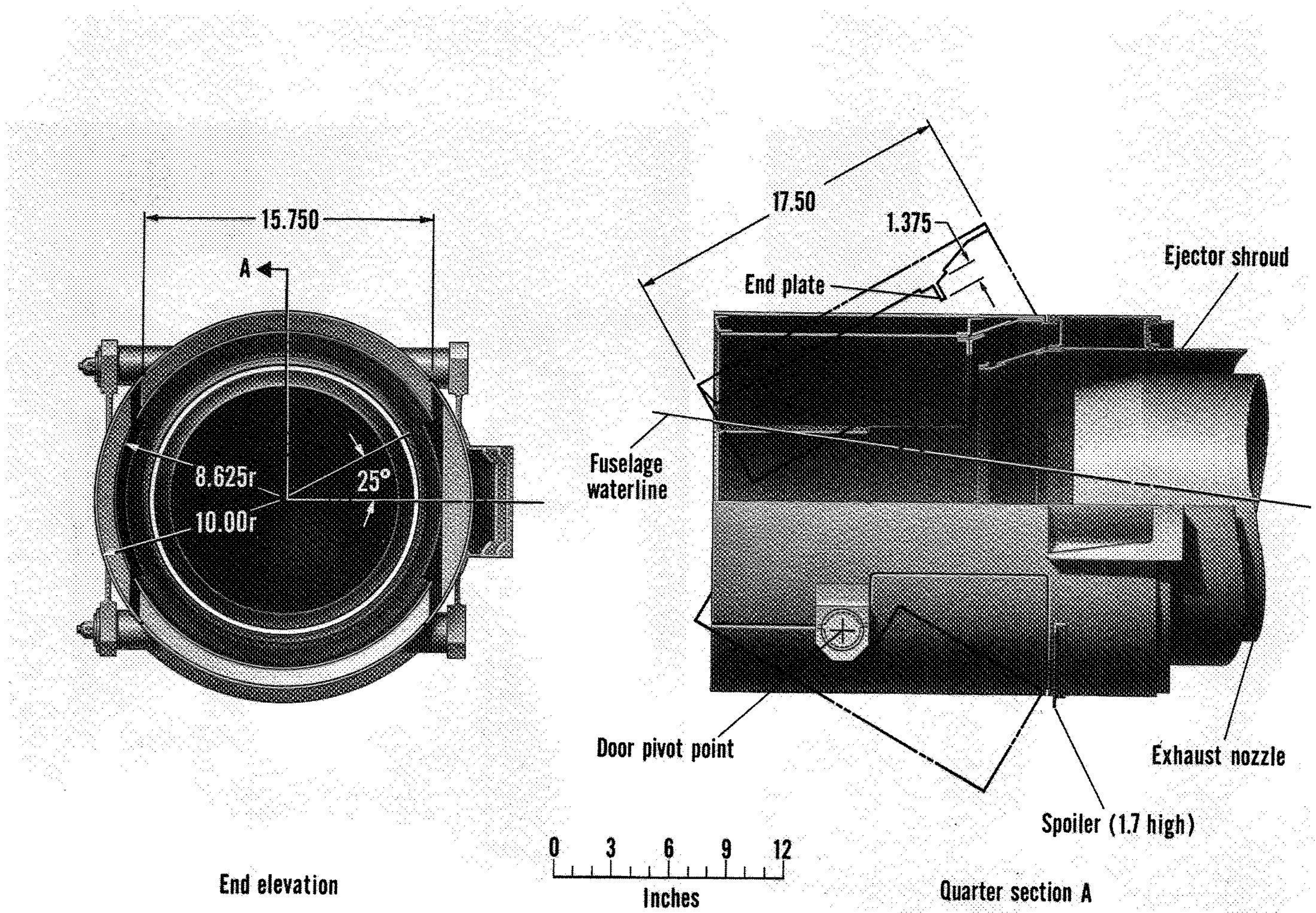
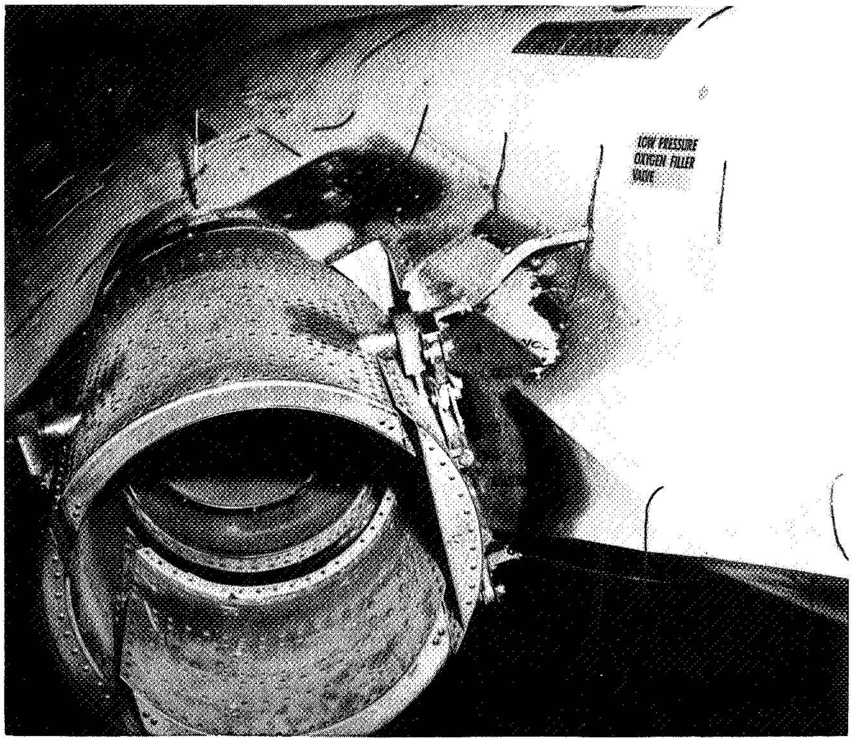
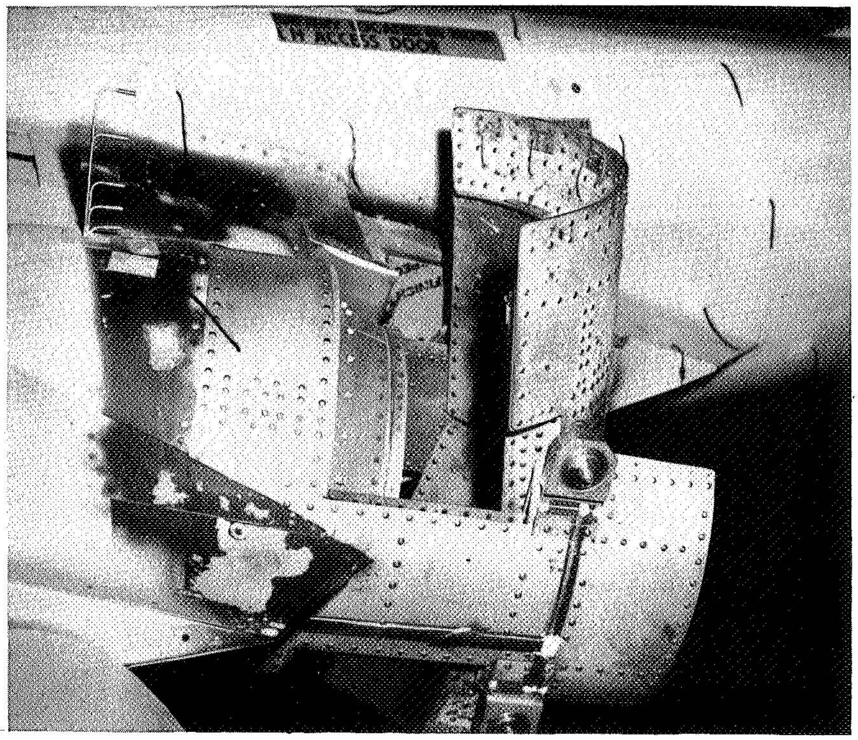


Figure 3.- Thrust reverser details.



(a) Reverser stowed; door gap = 17.4 inches.



(b) Full reverse; door gap = 0.

Figure 4.- Thrust reverser installed on aircraft.

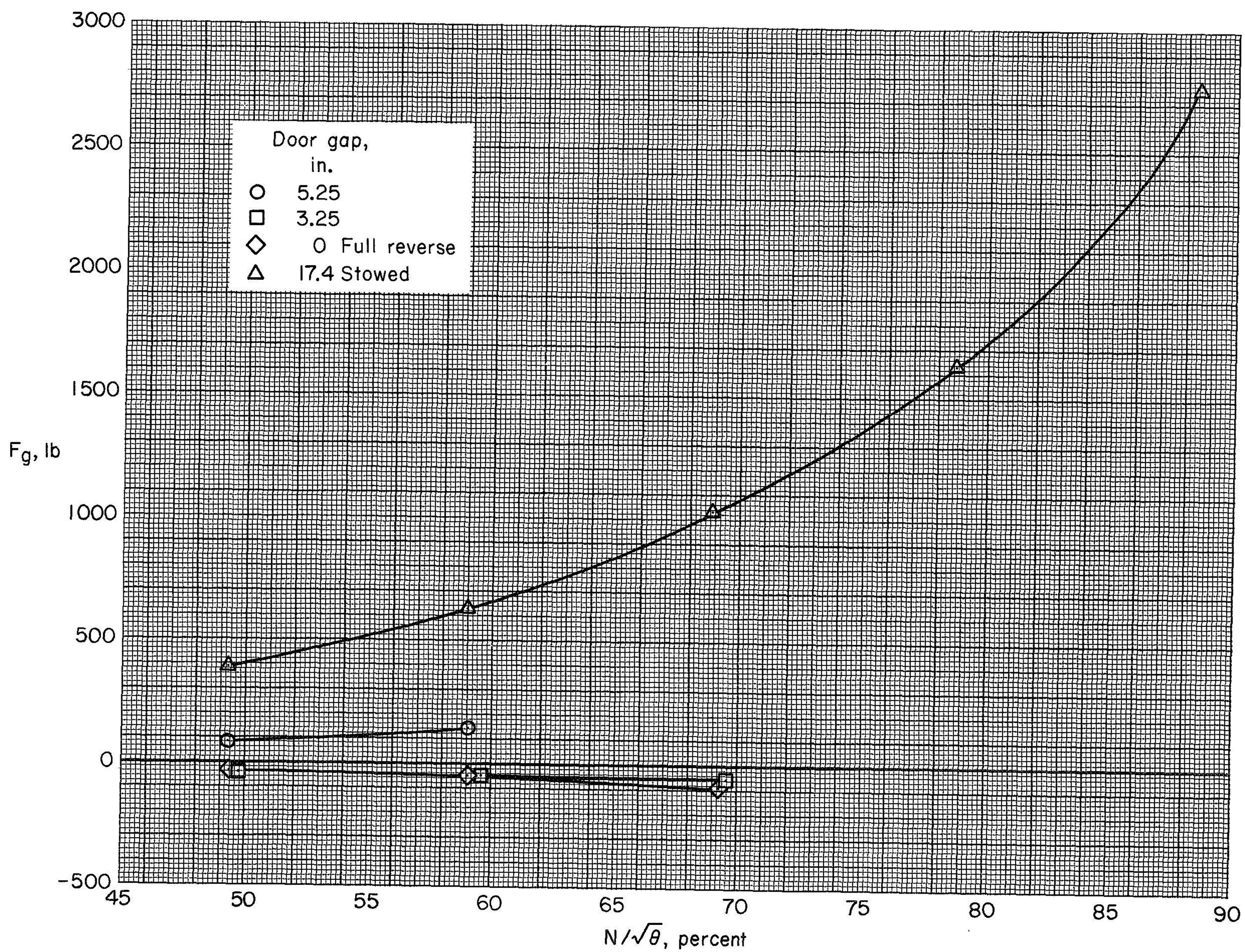


Figure 5.- Variation of gross thrust with changes in corrected engine speed for various door gaps; q = 0.

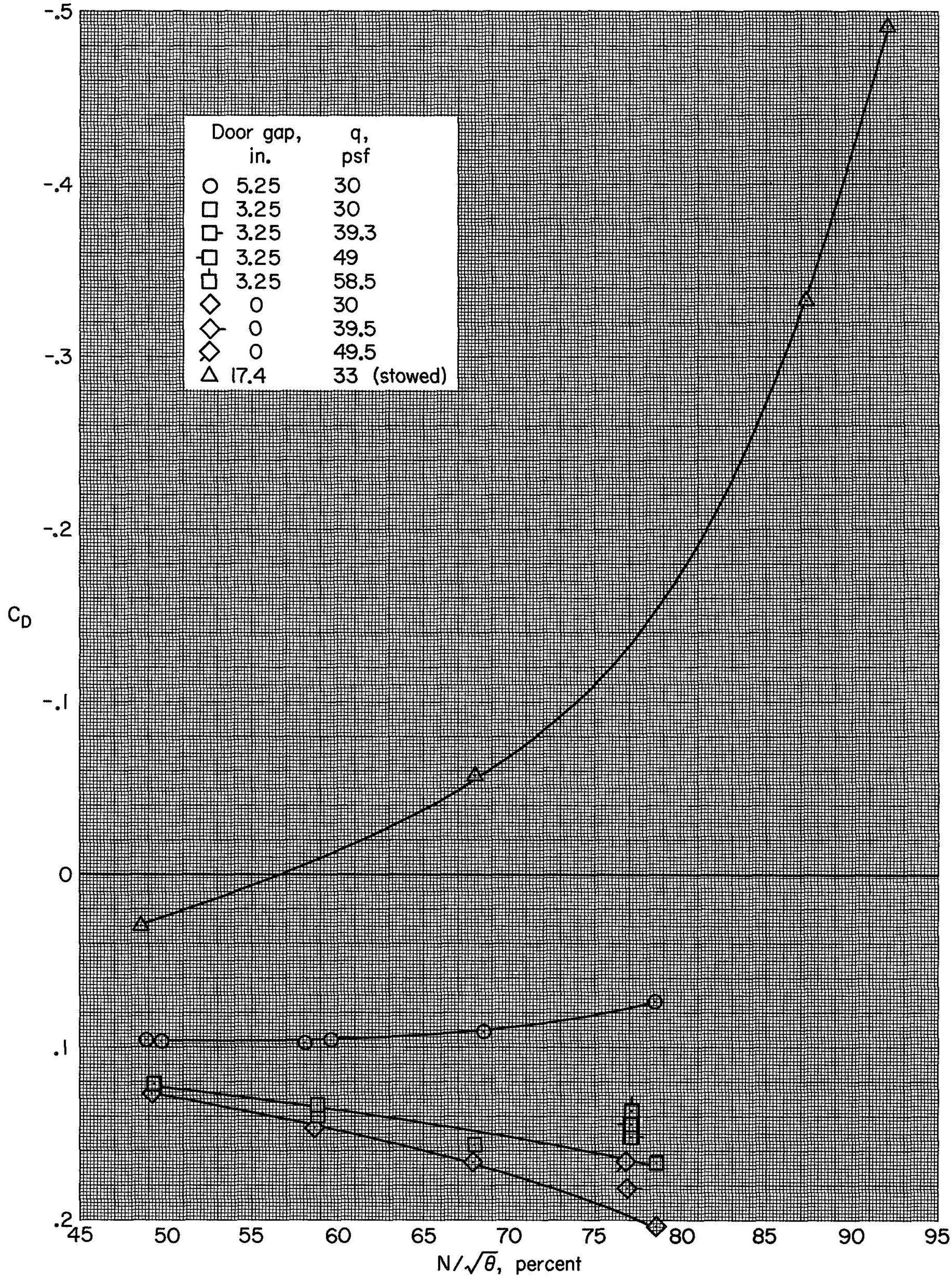
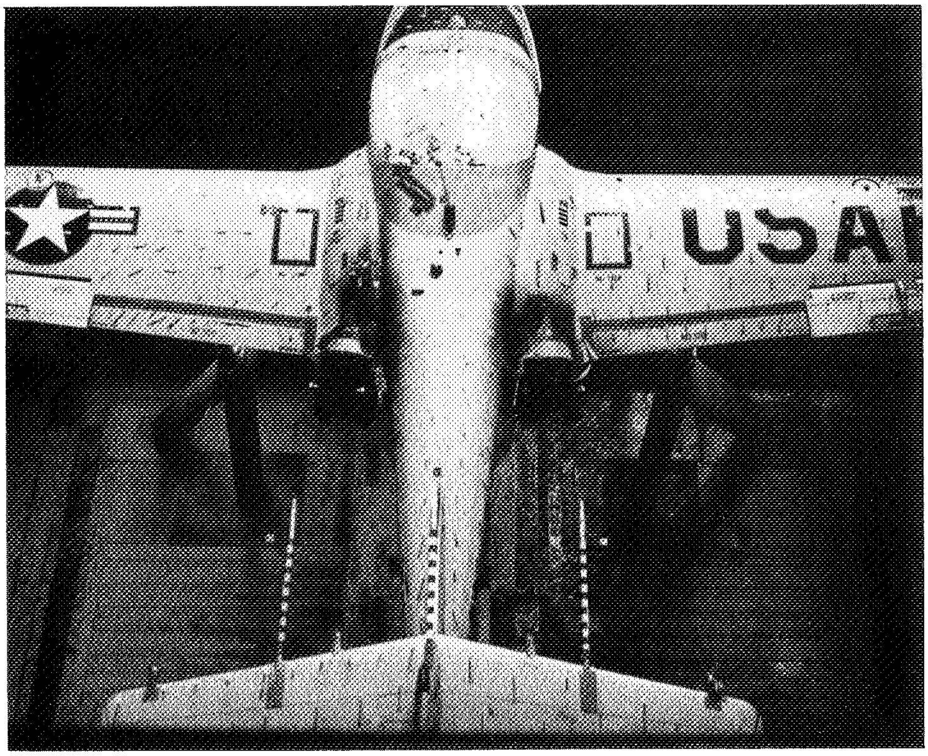
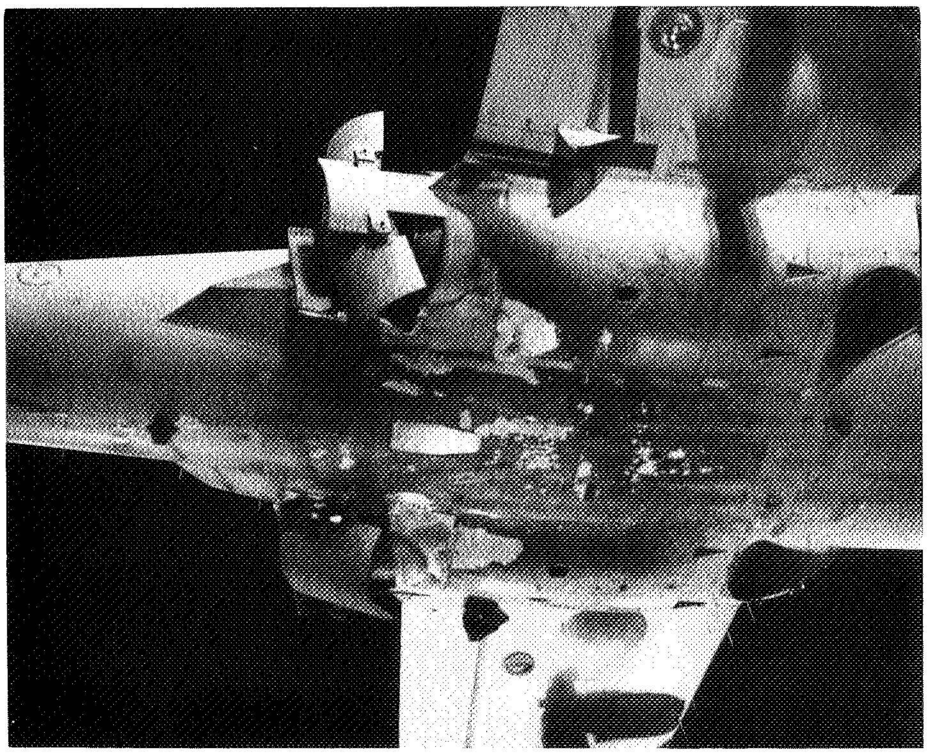


Figure 6.- Variation of drag coefficient with changes in corrected engine speed for several door gaps; α = 0°.

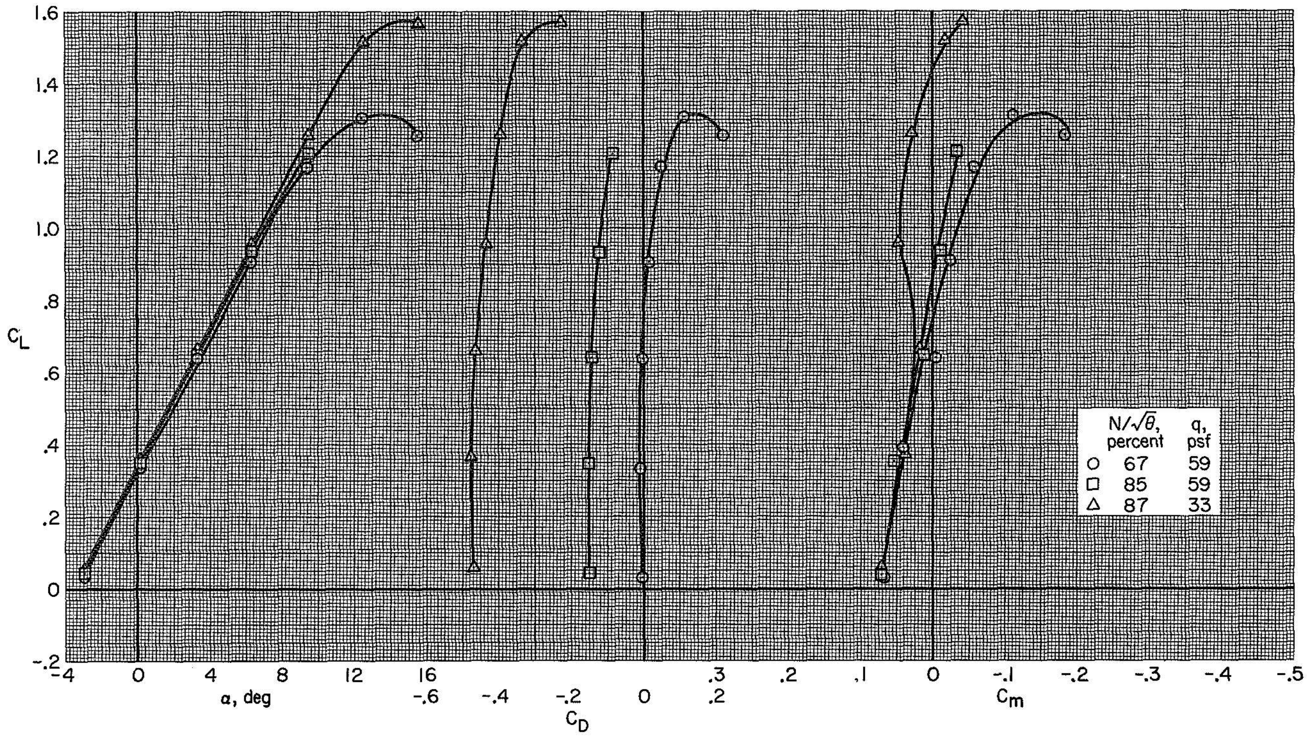


(a) Upper nacelle.

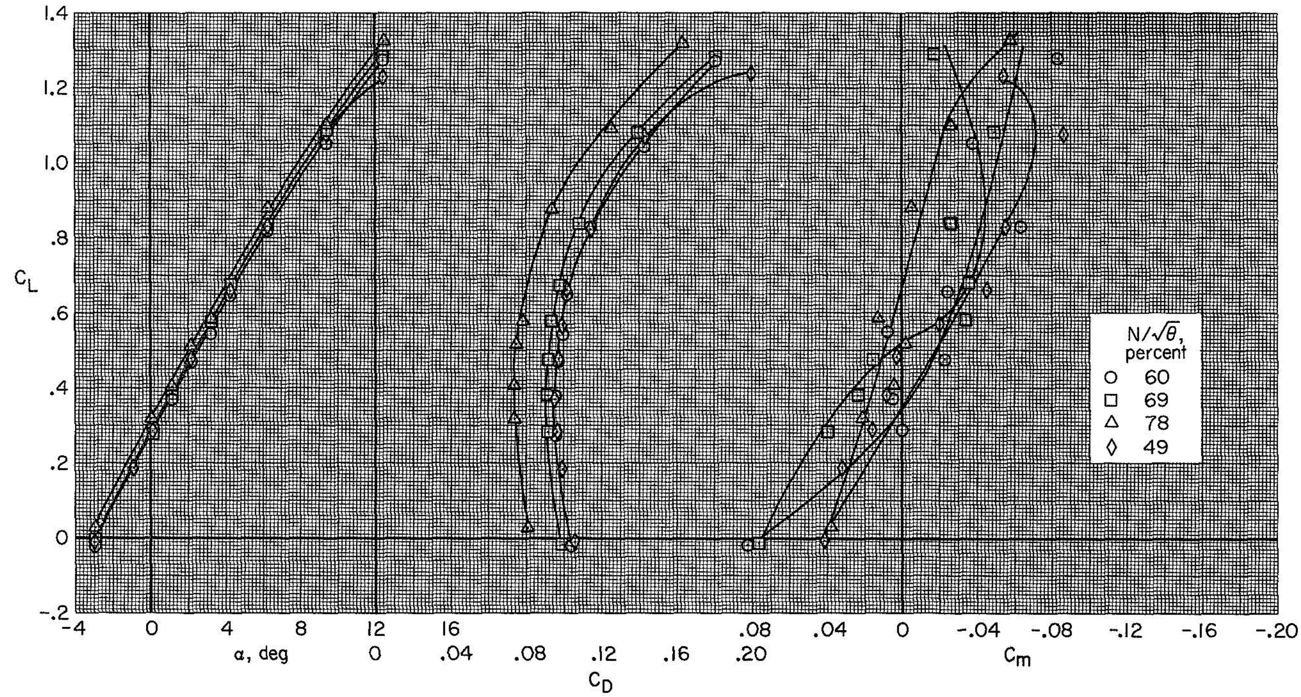


(b) Lower nacelle and fuselage.

Figure 7.- Discoloration and skin distortion caused by reverser exhaust gases.

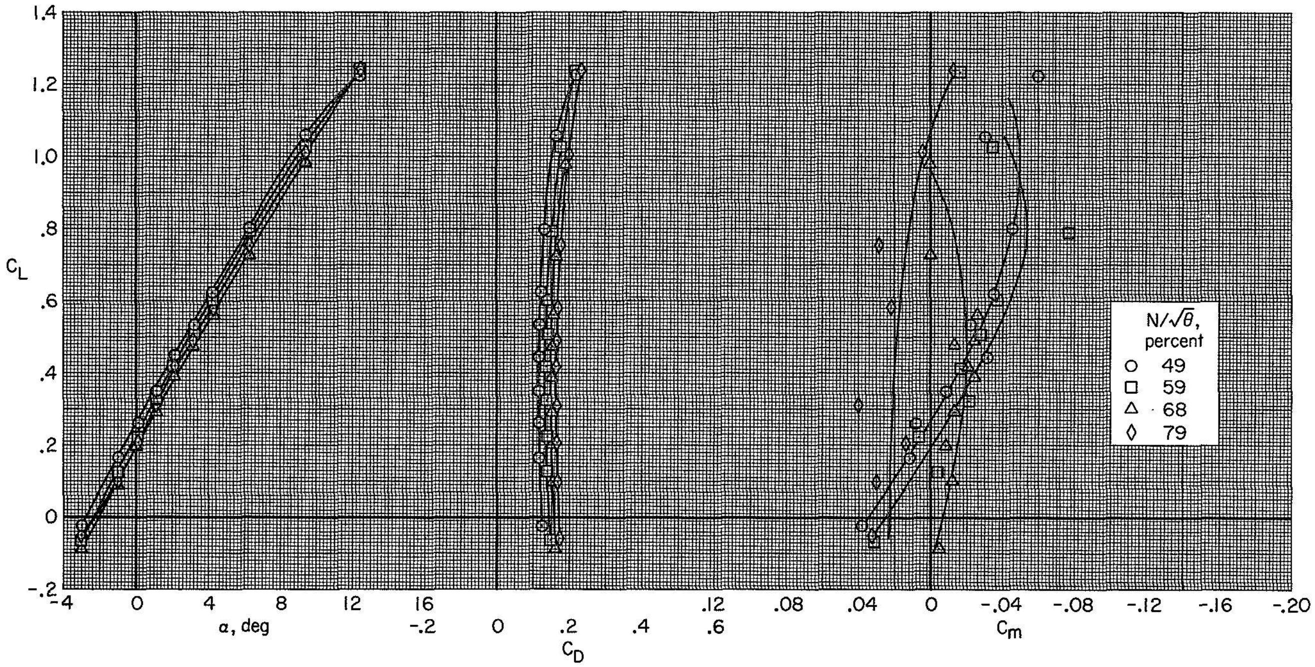


(a) Door gap = 17.4 inches (stowed).

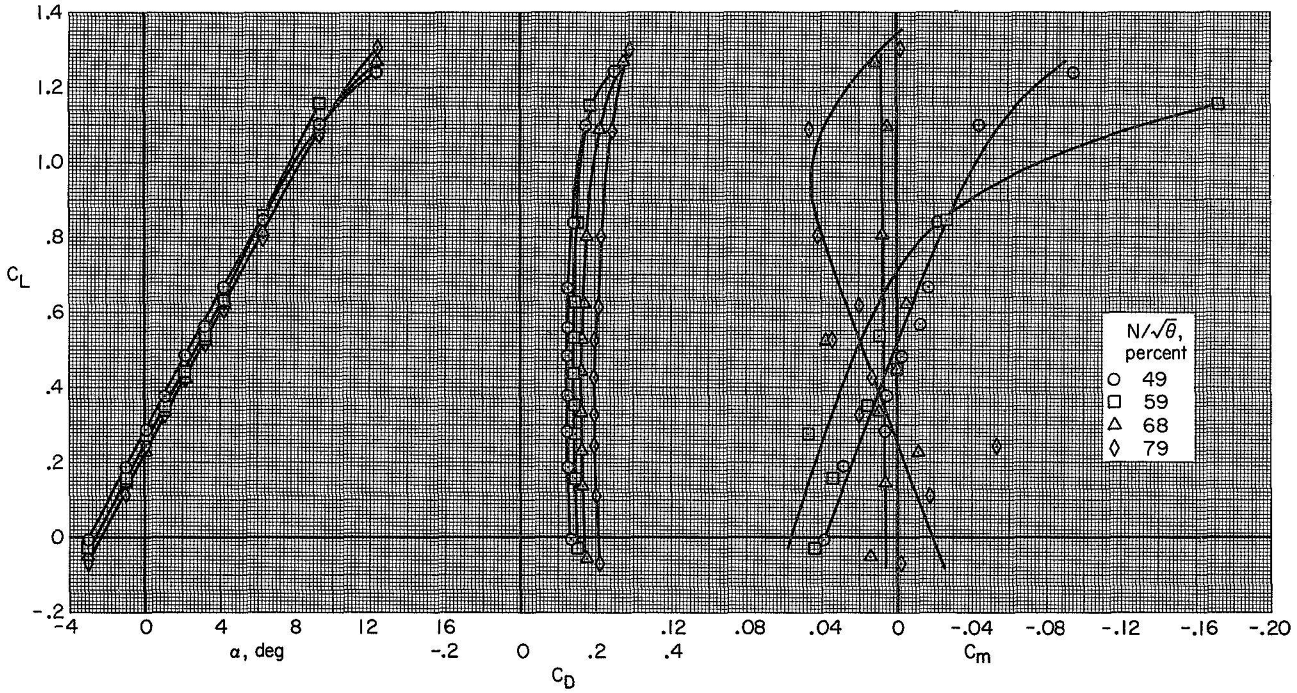


(b) Door gap = 5-1/4 inches; q = 30 psf.

Figure 8.- Variation in longitudinal characteristics with changes in corrected engine speed; $\delta_e = 0$.



(c) Door gap = 3-1/4 inches; q = 30 psf.



(d) Door gap = 0; q = 30 psf (full reverse).

Figure 8.- Concluded.

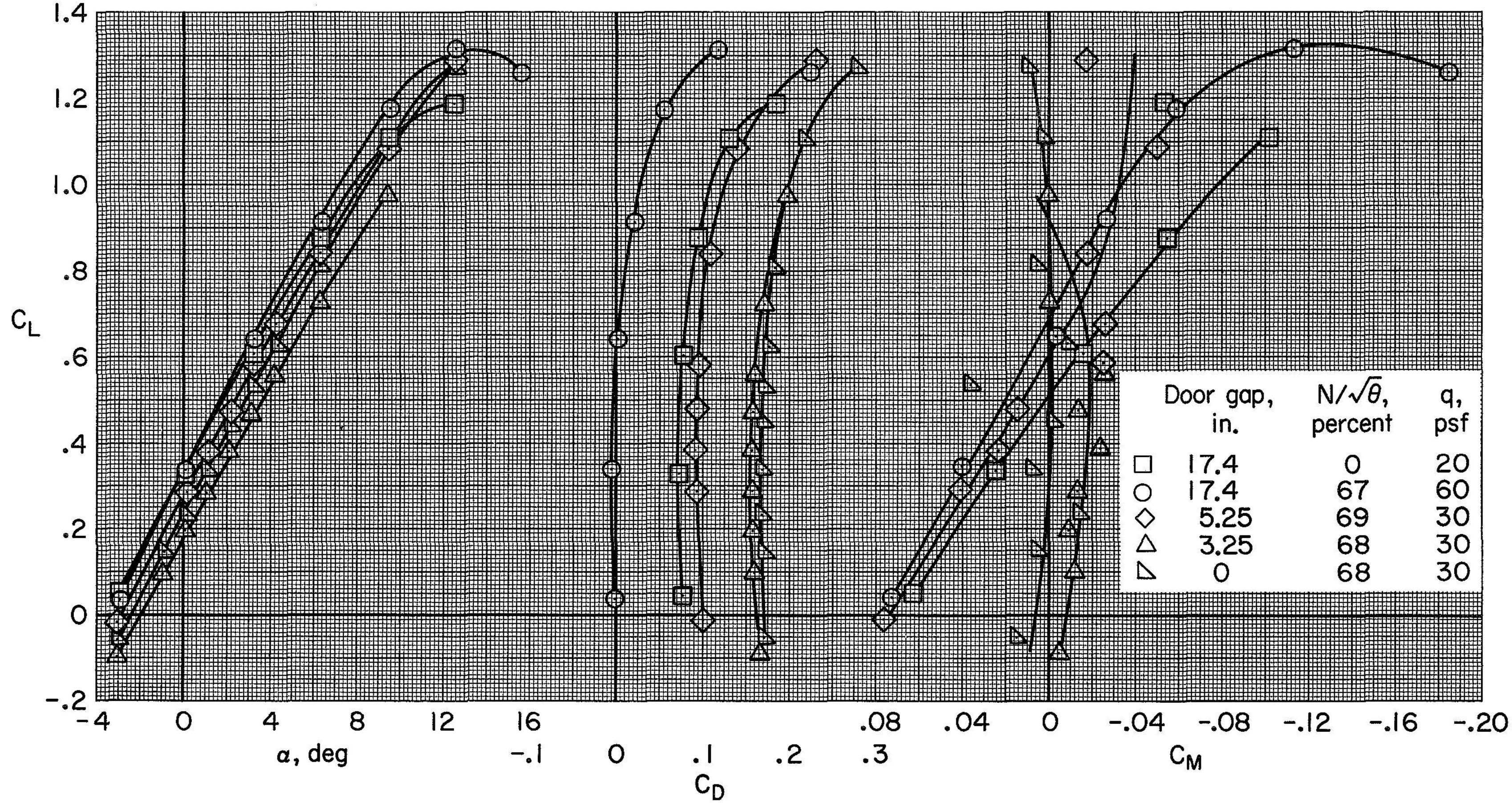


Figure 9.- Variation in longitudinal characteristics with changes in reverser door gap; $\delta_e = 0$.

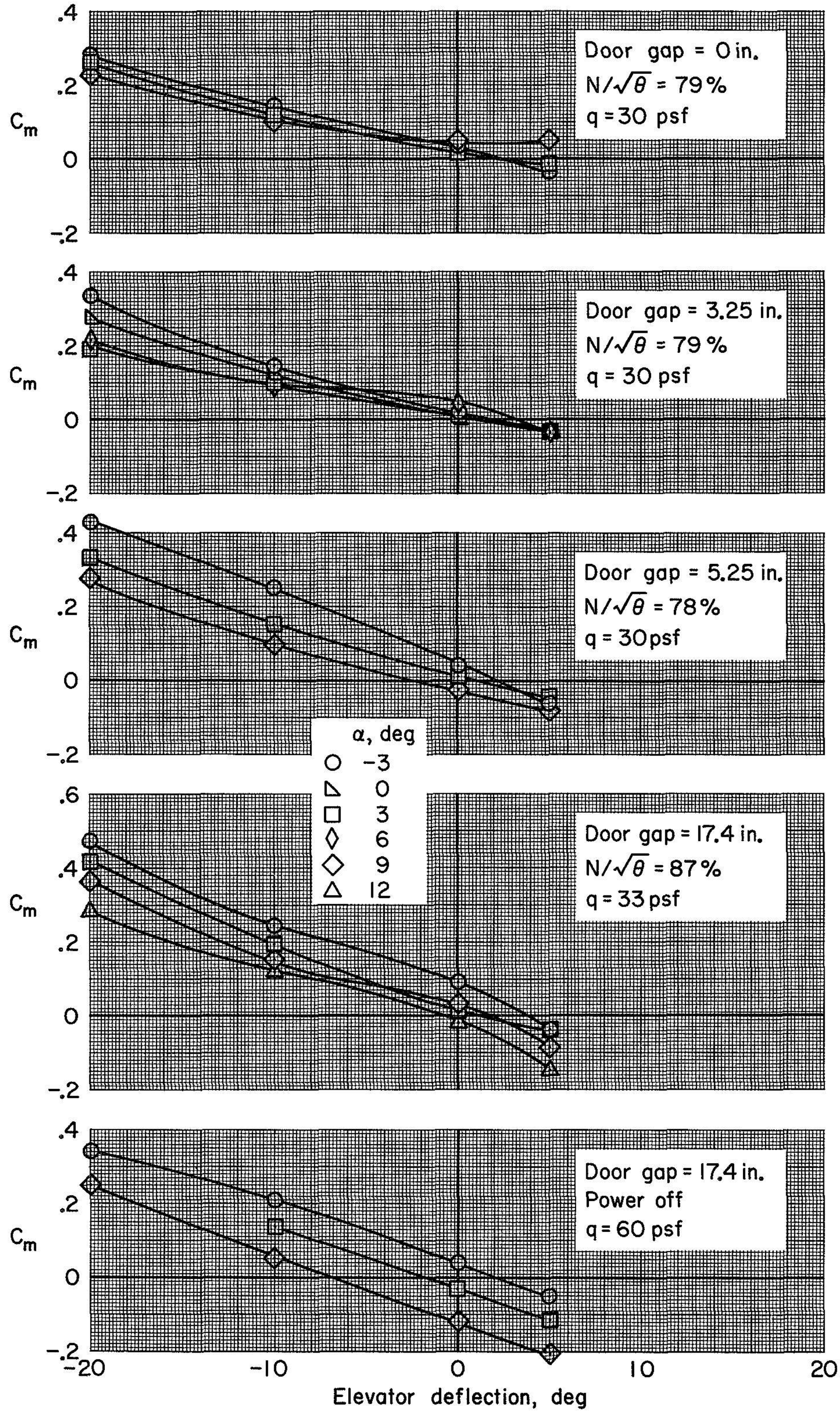


Figure 10.- Variation of longitudinal control effectiveness with changes in door gap.

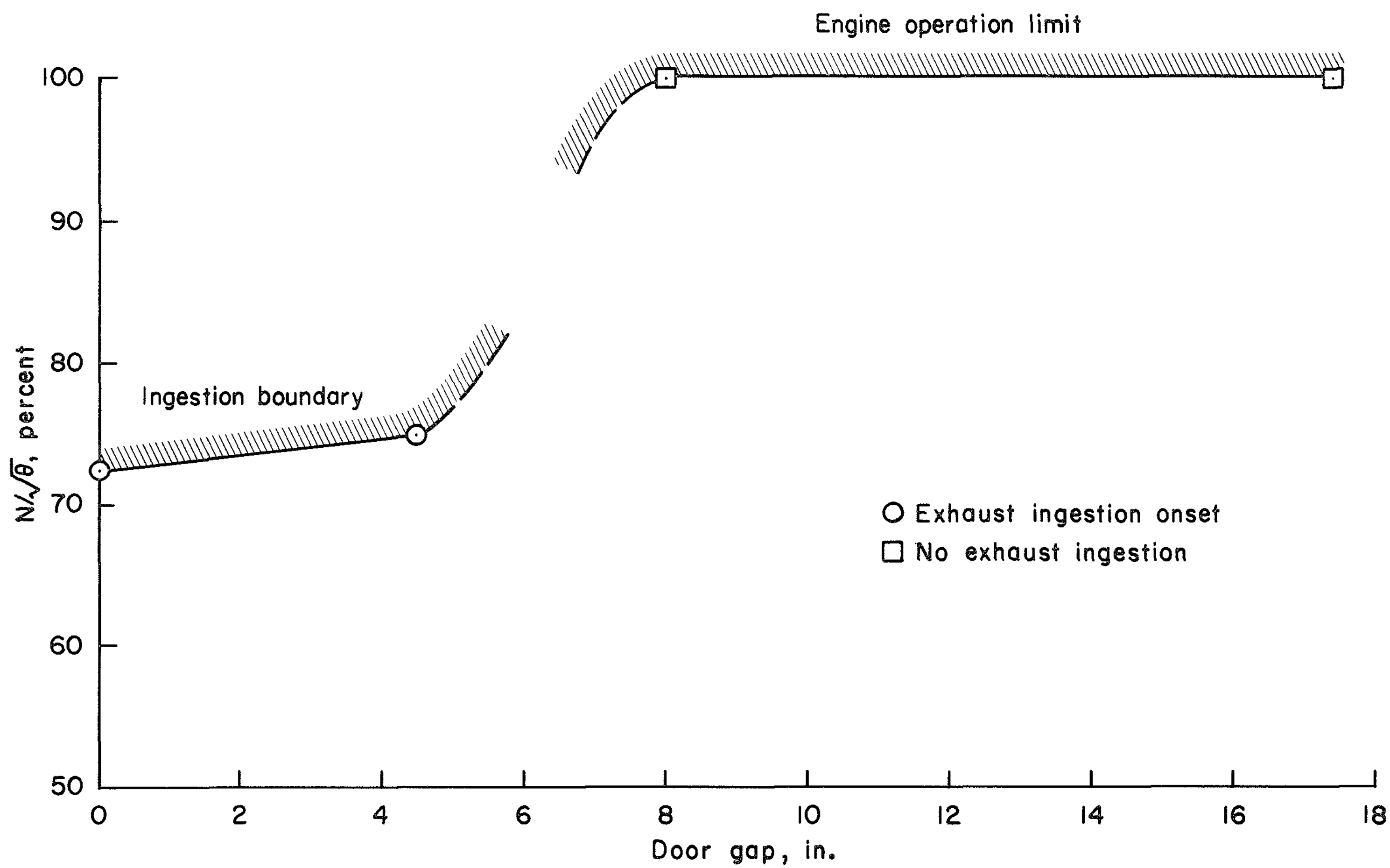


Figure 11.- Variation in engine speed at exhaust ingestion onset with changes in door gap; ground plane installed, q = 30 psf, $\alpha = 0^{\circ}$, flap deflection = 0°.

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